

Final Report

Visual function in Chesapeake Bay sportfishes: striped bass, weakfish, spotted seatrout, Atlantic croaker, spot, and red drum

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Prepared by

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None of this work would have been possible without funding support of the RFAB, and interest from local fishermen and fishing groups.

SUMMARY OF WORK

Electroretinographic data were obtained from six species, including striped bass (*Morone saxatilis*), weakfish (*Cynoscion regalis*), spotted seatrout (*Cynoscion nebulosus*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), and red drum (*Sciaenops ocellatus*). Spectral sensitivity (color vision) and Flicker Fusion Frequency (speed of vision) were obtained from averages of the six best day and night recordings to produce the mean response for each species during each diel period. The results for each species are discussed in terms of visual acuity, habitat utilization, and feeding ecology.

INTRODUCTION

General analyses of body shape and structure suggest that vision is an important mechanism affecting predation success in striped bass, spotted seatrout, and weakfish. In contrast, bottom feeding fishes such as Atlantic croaker, spot, and red drum, may use sight along with touch and taste to find prey (Hartman and Brandt, 1995; Chao and Musick, 1977). Color vision, visual acuity, and speed of vision are important adaptations in fishes as they affect the recognition of mates and fellow conspecifics (Guthrie and Muntz, 1993; Kynard et al., 2002), the avoidance of predators (Poling and Fuiman, 1999), and the location and capture of prey (Browman et al., 1994). Predation influences the structure and dynamics of aquatic communities, but little is known about how estuarine predators such as striped bass, weakfish, spotted seatrout, Atlantic croaker, spot, and red drum use visual cues to detect their prey because a complete description of visual function in these fishes is lacking.

Very little is known about the color vision of sportfish species despite the importance of vision to the predatory success of recreationally important fishes. Understanding the importance of vision in predator-prey interactions has important consequences for testing community-level trophic interactions and foraging models. Specifically, the visual capabilities of fishes to discriminate and select prey, based on cues such as size and color, are central to estimating prey encounter probabilities required for predator-prey interactions models (Walton et al., 1997). This is especially important considering the interactions of predatory species that feed primarily during the day in brightly lit surface waters (i.e. croaker, spotted seatrout, spot) with those that often feed at night or at depth (i.e., striped bass and weakfish) (Hartman and Brandt, 1995). This suggests differences in color sensitivities, visual acuities, and capacities for effective vision in dim light, and ultimately resulting in different prey detection capacities. An evaluation of the visual abilities of these species is likely to reveal important mechanisms driving the predatory or competitive advantages of some sportfish species over others under different visual conditions (Vogel and Beauchamp, 1999). Moreover, by constructing equations relating the combined effects of light and turbidity on predator reaction distances, the prey detection capabilities of piscivores can be modeled as a function of depth and time in natural environments (Vogel and Beauchamp, 1999).

Research into the link between vision and predation is especially critical in turbid water. The relationship between absolute prey availability (number of prey per unit area) and consumption (number of prey eaten in a given area) is commonly assessed by researchers during predator-prey interaction studies. However, a more accurate operational measure of predation availability would be the visual abundance of prey to a

visually-feeding predator – prey that aren't seen by visual feeders aren't really available to them (Browman, 2005). We know very little about the visual performance of most marine sportfishes, including those in this proposal. Recent work in other ecosystems suggests that increased turbidity should limit the predatory success of piscivorous fishes far more than the feeding success of planktivores. Murky waters may actually serve as a refuge from predation by piscivores because the poor water clarity allows them to escape attack and virtually disappear from the visual field of their piscivore predators (Johnsen, 2005). Turbidity should also favor tactile benthic predators over visual pelagic predators, a particularly interesting concept in light of recent differences in relative abundance among the species in this protocol. Data on the visual performance of Chesapeake Bay's sportfishes will allow us to continually assess the validity of this theoretical work in coming years.

This report summarizes the findings of a project been funded by the Virginia Marine Resources Commission's Recreational Fishing Advisory Aboard to use state-of-the-art electroretinographic (ERG) techniques to assess the color vision, visual acuity (i.e., the ability to differentiate separate objects at a distance), and speed of vision of several important sportfishes in Chesapeake Bay: striped bass (*Morone saxatilis*), weakfish (*Cynoscion regalis*), spotted seatrout (*Cynoscion nebulosus*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), and red drum (*Sciaenops ocellatus*).

METHODS:

Obtaining specimens: We experienced high levels of success with the following protocol of obtaining, transporting, and keeping these animals in captivity for experiments. Animals were generally caught on natural or artificial baits using medium-light sportfishing tackle (8-12 lb test) during our own sampling or via recreational fishing contacts in collaboration with Jon Lucy (VIMS) and Captain Steve Wray (Long Bay Pointe Bait and Tackle). After capture and dehooking, fishes are placed in 100-300 gallon tanks equipped with aerators and are transported by truck or boat to the VIMS animal holding facilities. Once in our holding facilities at the Eastern Shore Laboratory in Wachapreague, Virginia, animals were maintained in 450 gallon flow-through tanks at 25 C (77F) and were fed ad libitum every other day.

We maintained our research specimens on a combination of biomedical-grade fish flake feed, frozen menhaden and tilapia, squid, blue crab, clam, whelk, and live killifish. Marine fishes become limited with respect to B- and C-vitamins in captivity; this only becomes a problem if the fish are kept for more than a few months. This flake food is infused with all 20 essential amino acids, a full complement of vitamins, and an ideal protein:fat:carbohydrate ration for animal maintenance. Our fishes feed aggressively, retain their color, and remain healthy and active.

Computer and electrophysiological technology: A schematic summary of the electroretinographic experimental setup for fish color vision, dynamic range, and speed of vision is presented in Figure 1. During ERG experiments, electrodes are placed on the cornea and subdermally in the dorsal musculature to measure retinal response to synchronized light stimuli. Flashes of light of various frequencies (i.e., colors) and

amplitudes (i.e., brightness) are presented and responses recorded via a custom designed computer-controlled system.

We reconfigured and recalibrated the elaborate software programs and hardware attachments to sample both flicker fusion frequency (speed of vision) and spectral sensitivity (color vision) of estuarine fishes *in vivo* (i.e. whole animal) in our winter-spring-fall Byrd Hall research facility in Gloucester Point and in our summer Davis Hall facility in Wachapreague, Virginia. The calculations associated with this change in protocol and the sheer volume of software programming were extremely time consuming endeavors. In moving between laboratories, we restructured the hardware-software connections and recalibrated the illuminance of the lamps used in experiments – a very labor-intensive process – to allow for the standardization of quantal energy (number of photons) stimulating the retina at each “color”. Repeated testing generated accurate and consistent results.

Unfortunately, we lost 10 summer research days due to a malfunction of our monochromator, which controls the intensity of our light stimulus. Basically, the unit’s UV-grating became worn due to high use, causing contamination of the stimulus light field by UV rays and bright white light. In other words, we lost the ability to present pure color stimuli during vision trials. The unit was rapidly repaired by the manufacturer and returned to service.

RESULTS

Overall, about 20% of all recordings failed to produce high-quality data due to low signal-to-noise ratios, biological/individual (subject) variability, or technical difficulties. Electrical noise and electrode failure were the two most common problems. In extreme cases, whole individuals were rejected from this study due to poor response quality. We obtained high-quality spectral sensitivity (SS: color vision) and flicker fusion frequency (FFF: speed of vision) data from six striped bass, six weakfish, five spotted seatrout, six croaker, six spot, and six red drum. For each specimen, day and night recordings were completed for both spectral sensitivity, dynamic range, and flicker fusion frequency experiments.

All species can discriminate green (including chartreuse) – in many cases, the green/yellow border is seen extremely well, which may explain the generally good performance of chartreuse-colored baits. Our results indicate interesting species-specific differences in the spectral sensitivity (color vision) and dynamic range (dim-to-bright light range) and speed of vision (flicker fusion frequency) of the retinas of study animals:

Striped bass (Fig. 2): During daylight hours, striped bass were the only species that responded well to stimuli in the longer (red) wavelengths. This species exhibited a nocturnal blue-shifting of the color spectrum, meaning that they responded better to shorter (blue) wavelengths than the longer orange-red wavelengths at night. Striped bass have the most limited daytime dynamic range (2 orders of magnitude), but became 100 times more light sensitive at night. This species also had the highest FFF (fastest vision) of any fish in this study, nearing the speed of human vision (60 Hz). The striped bass eye appears to have specialized for daytime feeding via color discrimination and fast vision. Chesapeake Bay’s turbid water are not advantageous to an eye design that is tailored to high wavelength colors (red) and fast, bright light vision, thus striped bass may be at a

competitive visual disadvantage in Chesapeake Bay relative to some of the other species studies. This effect may possibly explain recent trends in striped bass diet showing fewer high-energy large prey items and more lower-quality benthic food sources (Latour, unpublished).

Weakfish (Fig. 3): Weakfish respond well from the very short wavelength UV-A (350-400 nm) stimuli, wavelengths blocked by the eye lenses of the other species in this proposal, to orange. UV-A vision is most common in nocturnal animals, but it comes with a tradeoff because UV wavelengths are damaging to retinal cells, causing most UV-sensitive animals avoid bright, direct sunlight (Leech and Johnsen, 2003). The benefit of UV vision is to enhance the contrast of small, cryptic, or camouflaged objects against the background spacelight (Leech and Johnsen, 2003). UV vision in weakfish may allow the species to use contrast enhancement to feed during periods of high UV irradiation and/or low ambient light (dawn, dusk, and at night). The dynamic range of weakfish suggests that they are equally and highly light-sensitive day and night. Weakfish had the slowest vision of any species in this study, nearing the ultra-slow, nocturnal eyes of swordfish. Slow vision is also common in animals inhabiting dark environments and in nocturnal species (Warrant, 1999). The slow and blue/UV sensitive weakfish eye thus appears well-adapted for foraging at night and in dim light conditions, such as those commonly encountered at depth in the present-day Chesapeake Bay. Weakfish and striped bass appear to compete for some fish prey, and are often simultaneously collected together in the field (Hartmann and Brandt, 1995). With respect to vision, however, it appears that these two competing predators live side-by-side in different spectral worlds.

Spotted seatrout (Fig. 4): Spotted seatrout responded to intermediate wavelengths, from blue (peak) through orange. This species becomes more blue-sensitive at night, when blue wavelengths are more dominant in the ambient spacelight. The dynamic range of spotted seatrout was equally and highly light-sensitive day and night. This species had fairly average visual speed (~30 Hz).

Red drum (Fig. 5): Red drum responded to intermediate wavelengths, from blue (peak) through the orange/red border, and lacked a day-night shift in color sensitivity. The dynamic range of red drum was equally and highly light-sensitive day and night. This species had fairly average visual speed (~33 Hz).

Atlantic croaker (Fig. 6): Atlantic croaker responded to intermediate wavelengths, from blue (peak) through orange. This species becomes more blue-sensitive at night, when blue wavelengths are more dominant in the ambient spacelight. The dynamic range of croaker was equally light-sensitive day and night, suggesting that this species' eye performs well under dim conditions (such as the bay bottom) night. The dynamic range was, however, more limited than the range of other species in this proposal: the response plateaus at the brightest intensities, suggesting that croaker retinas are not adapted well to function in bright light, because they spent most of their time in association with the benthos in deeper, dimmer waters. This species had fairly average visual speed (~30 Hz).

Spot (Fig. 7): Spot responded to intermediate wavelengths, from blue (peak) through orange. This species becomes more green-sensitive at night. The dynamic range of spot suggested slightly higher light sensitivity light-sensitive at night than during the day. Like the effect seen in croaker, the dynamic range of spot was more limited than the range of other species in this proposal: the response plateaus at the brightest intensities, suggesting that croaker retinas are not adapted well to function in bright light, because they spent most of their time in association with the benthos in deeper, dimmer waters. This species had fairly average visual speed (~32 Hz).

We have made the preliminary results of this study available to the Virginia Angling community by presenting at local fishing organization meetings. A. Horodysky presented at the October meeting of the Virginia Beach Angler's club (10/06/05) and gave a talk at the December meeting of the Peninsula Salt Water Sport Fisherman's Association (12/20/05). This meeting was well-received, and was attended by C. Randolph and S. Davis. Additionally, we hosted a very successful red drum vision experiment attended by board members Duell, Randolph, Southall and Ms. Davis on Mon 6 Feb. A. Horodysky presented our vision results on June 7 at the VIMS Eastern Shore Laboratory Evening Public Seminar Series and at Boater's World on Wed, August 9th. Our work was presented in the summer edition of The Crest, a VIMS research publication (available at: http://www.vims.edu/newsmedia/pdfs/fish_vision82.pdf). We continue to welcome any such invitations to present results at meetings of local fishing organizations, and have fielded numerous public and media phone calls in the last month regarding this work.

Finally, we submitted the abstract below for presentation at two scientific meetings in 2006. This presentation will be based on results from our visual experiments funded by RF 05-14. RFAB's funding support is mentioned throughout the seminar. The conferences include:

1. 7th International Fish Biology Congress 18-22 July Newfoundland, Canada
2. American Fisheries Society 10-14 Sept Lake Placid, NY

Abstract:

ELECTRORETINOGRAPHIC ASSESSMENT OF VISUAL FUNCTION IN SIX COMMERCIALY AND RECREATIONALLY IMPORTANT ESTUARINE FISHES.

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Little is known about how differences in visual function reflect the lifestyles and feeding strategies of estuarine fishes. We therefore assessed day and night spectral sensitivities (color vision), light sensitivities, and flicker fusion frequencies (FFF: speed of vision) of six Chesapeake Bay fishes: striped bass (*Morone saxatilis*), weakfish (*Cynoscion regalis*), spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), Atlantic croaker (*Micropogonias undulatus*), and spot (*Leiostomus xanthurus*) using electroretinography (ERG). Subjects were presented light stimuli covering the spectral range from UV (300 nm) to the near infrared (800 nm) and six orders of magnitude of light intensity via a custom-designed computer-controlled system. Responses were corrected for equal quantal energy at each wavelength. Study animals demonstrated peak

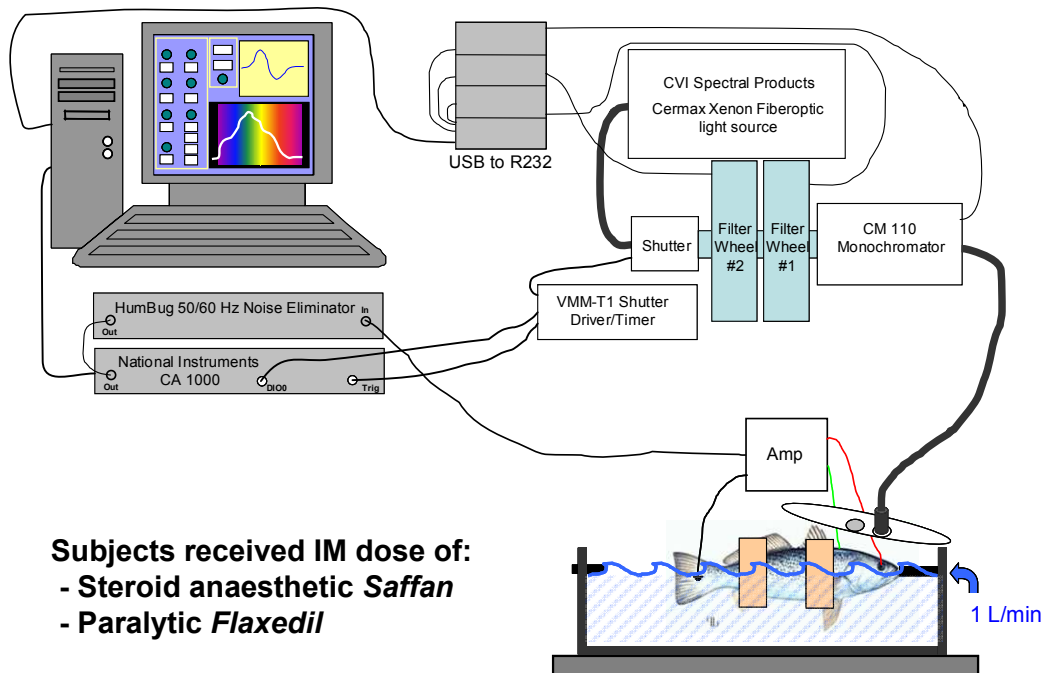
sensitivity between 450-575 nm, though retinograms showed strong species-specific differences. Weakfish responded to short wavelength UV light, while striped bass responded to the longer (red) wavelengths. Intensity-response and FFF experiments also revealed species-specific differences in dynamic range and speed of vision. The visual systems of these sympatric fishes thus appear to have evolved different functional characteristics that are reflective of their specific niches within the estuarine environment. Visual ecology bears important implications for predator-prey interactions, estimating prey encounter probabilities, and ultimately understanding community-level trophic interactions. Funded by Recreational Fishing Advisory Board, Virginia Marine Resources Commission.

Mr. Horodysky presented this research at the Newfoundland, Canada meeting (1) on 21 July. The data were very well received. This talk stimulated much discussion regarding how little is known about estuarine fish vision in general and especially within related groups, and several researchers commented that the involvement of the recreational fishing community both as a funding source and for providing subjects was a wonderful example of cooperative research.

Literature Cited:

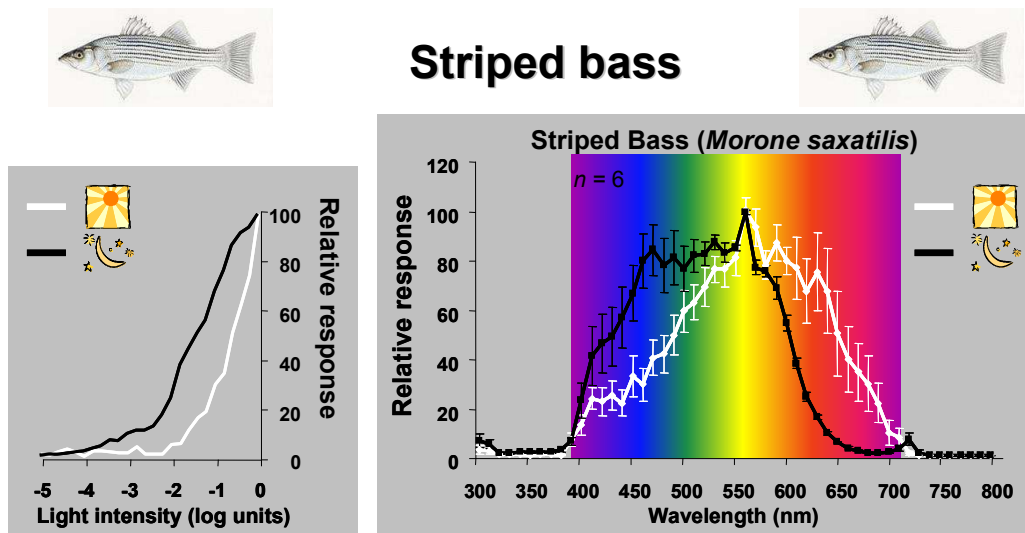
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Methods: ERG



Spotted seatrout image by D. Peebles

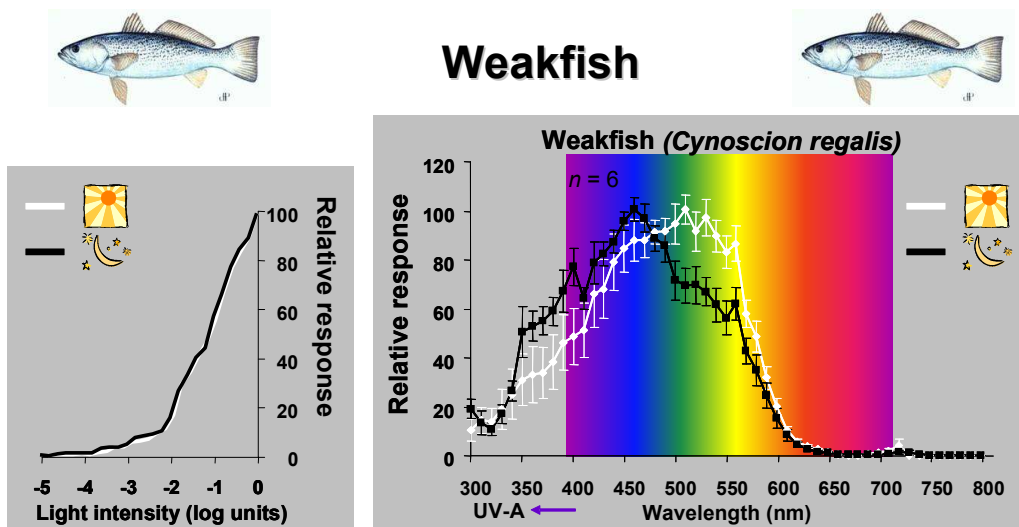
Figure 1



- **Striped bass:**
 - **Spectral sensitivity: nocturnal blue-shifting**
 - **Dynamic range: nocturnal increase ~ 2 orders of magnitude**
 - **Flicker Fusion Frequency: 55 Hz**

Striped bass image by J. Tomelleri

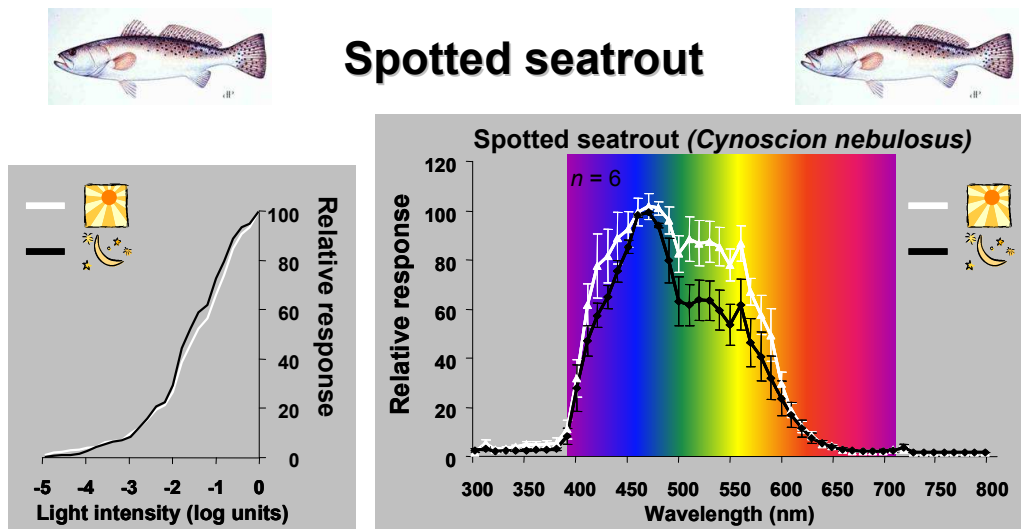
Figure 2



- **Weakfish:**
 - Spectral sensitivity: nocturnal blue- and UV-A shifting
 - Dynamic range: no diel differences
 - Flicker Fusion Frequency: 22 Hz

Weakfish image by D. Peebles

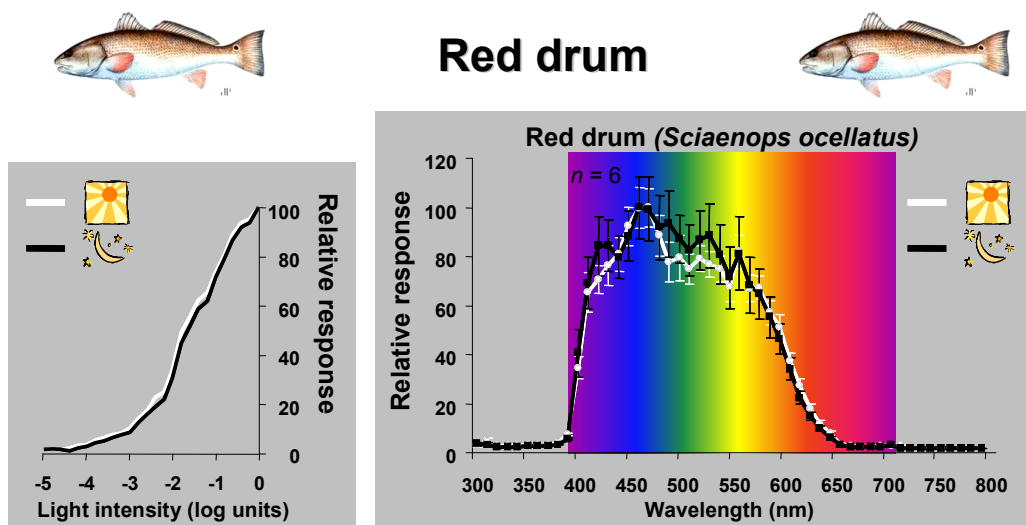
Figure 3



- **Spotted Seatrout:**
 - **Spectral sensitivity:** slight nocturnal blue-shifting
 - **Dynamic range:** no diel differences
 - **Flicker Fusion Frequency:** 30 Hz

Spotted seatrout image by D. Peebles

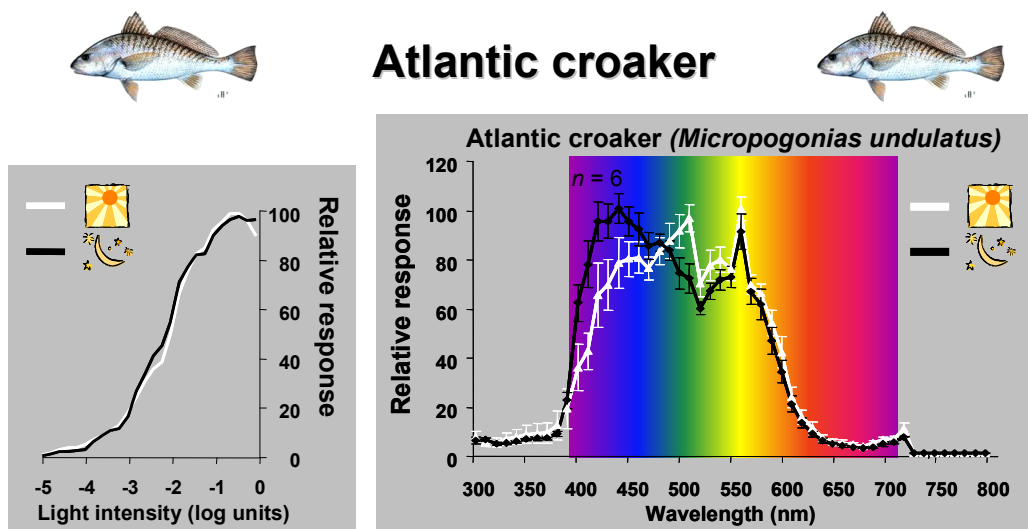
Figure 4



- **Red Drum:**
 - **Spectral sensitivity: no diel differences**
 - **Dynamic range: no diel differences**
 - **Flicker Fusion Frequency: 33 Hz**

Red drum image by D. Peebles

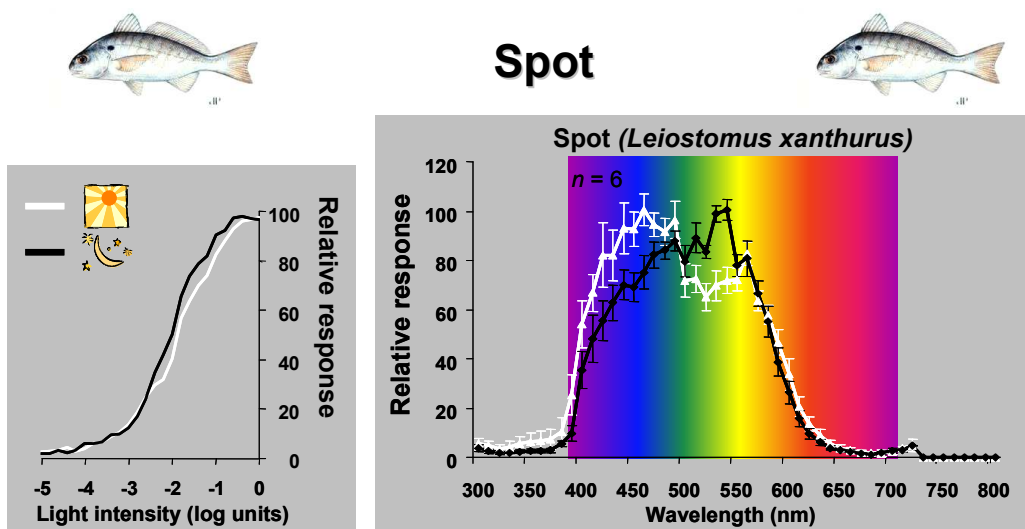
Figure 5



- **Atlantic croaker:**
 - Spectral sensitivity: slight nocturnal blue-shifting
 - Dynamic range: no diel differences
 - Flicker Fusion Frequency: 30 Hz

Atlantic croaker image by D. Peebles

Figure 6



- **Spot:**
 - **Spectral sensitivity:** slight nocturnal green-shifting
 - **Dynamic range:** v. slight diel differences
 - **Flicker Fusion Frequency:** 32 Hz

Spot image by D. Peebles

Figure 7